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DOI: https://doi.org/10.1016/j.ejcts.2006.03.048

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Journal Article
Published Version

Originally published at:
Plass, A; Grunenfelder, J; Leschka, S; Alkadhi, H; Eberli, F; Wildermuth, S; Zund, G; Genoni, M (2006). Coronary artery imaging with 64-slice computed tomography from cardiac surgical perspective. European Journal of Cardio-Thoracic Surgery, 30(1):109-116.
DOI: https://doi.org/10.1016/j.ejcts.2006.03.048

EUROPEAN JOURNAL OF
CARDIO-THORACIC
SURGERY

European Journal of Cardio-thoracic Surgery 30 (2006) 109—116

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Coronary artery imaging with 64-slice computed tomography from cardiac surgical perspective☆

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Received 6 November 2005; received in revised form 14 March 2006; accepted 20 March 2006

Abstract

Introduction: 64-Slice computed tomography (CT) has been introduced with high expectations. This study illustrates the value of 64-slice CT for the diagnosis of significant coronary artery stenoses when images are analysed by cardiovascular surgeons. **Methods:** Fifty patients (39 males, 11 females) underwent invasive coronary angiography and 64-slice CT. In these patients, 40 had coronary artery disease and 10 patients had valvular disease. Evaluation of right coronary artery (RCA), left main (LM), left anterior descending artery (LAD), diagonal branch 1 (D1), circumflex branch (CX), and 1st marginal branch was performed by two cardiovascular surgeons. All vessels with a diameter $\geq$1.5 mm were analysed and a lumen restriction of $>$50% was considered a significant stenosis. CT image quality was classified as excellent, reduced but still diagnostic, and not assessable. Invasive coronary angiography was taken as gold standard for calculations of diagnostic accuracy. **Results:** Mean heart rate during CT scan was 65 $\pm$ 11 beats per minute (bpm). Image quality of 92% (506/550) of all segments was rated as excellent, 5% (27/550) were rated as being of reduced quality but still diagnostic, and 3% (17/550) were considered not assessable. The sensitivity for diagnosing a significant stenosis with CT when including all reliably evaluated segments was 93% (106/114), specificity was 97% (381/392), positive predictive value was 91% (106/117), and negative predictive value was 98% (381/389). **Conclusion:** 64-Slice CT provides a high diagnostic accuracy in assessing significant coronary artery stenosis. Nevertheless, still exist some disadvantages such as strong vessel wall calcifications reducing the reliability for image interpretation. At the moment, 64-slice CT should be used as a complementary imaging modality to invasive coronary angiography.
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Keywords: 64-Slice computed tomography; Coronary angiography; Coronary artery disease

1. Introduction

Invasive coronary angiography (ICA) is still considered the method of choice for the diagnosis and then assessment of severity of coronary artery stenoses. However, the cost-extensive technique is associated with the danger of the invasive procedure and the inconvenience for the patient. Already the previous 16-slice CT scanner showed in multiple studies [1—3] promising results, but the incomplete evaluation of the coronary artery tree made its use in clinical routine impossible.

64-Slice computed tomography (CT) recently has been introduced with high expectations. It provides an increased spatial and temporal resolution compared to the previous scanner models. The new kind of imaging technique provides isotropic voxels down to 0.4 mm^3 with a maximum temporal resolution of 83 ms [4].

It is generally the rule that cardiovascular surgeons themselves analyse the ICA in addition to the cardiologists prior to bypass surgery. When 64-slice CT would be intended to complement or even replace ICA, CT image analysis prior to surgery should be consequently also performed by the operating surgeon.

The goal of this study was to investigate the diagnostic accuracy of 64-slice CT with regard to coronary artery stenoses for preoperative planning of coronary artery bypass grafting (CABG) when image analysis is performed

Abbreviations: CAD, coronary artery disease; CT, computed tomography; CX, circumflex artery; ICA, invasive coronary angiography; LAD, left anterior descending artery; MIP, maximum intensity projection; MPR, multi-planar reconstruction; PACS, picture archiving and communicating system; RCA, right coronary artery; VRT, volume rendering technique

☆ Presented at the joint 19th Annual Meeting of the European Association for Cardio-thoracic Surgery and the 13th Annual Meeting of the European Society of Thoracic Surgeons, Barcelona, Spain, September 25—28, 2005.

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doi:10.1016/j.ejcts.2006.03.048

by cardiovascular surgeons. The results of 64-MSCT were compared to routine results of coronary angiography.

2. Methods

2.1. Patients

64-Slice CT was performed in addition to ICA in 50 elective patients (39 male, 11 female, age 66 ± 8 years) in sinus rhythm. These patients were divided in a *study group* of 40 patients (34 males, 6 females) and a *control group* of 10 patients (5 males, 5 females).

The *study group* included patients with coronary artery disease (CAD); the *control group* consisted only of patients with valve disease and inconspicuous coronaries.

As cardiovascular risk factors of all examined patients were evaluated: *smoking*, *obesity*, *hypertension*, *diabetes mellitus* and *high blood cholesterol*.

Risk factors of the *study group*:

- Smoking → 37/40 patients
- Obesity → 16/40 patients
- Hypertension (RR ≥ 140/90 mmHg) → 16/40 patients
- Diabetes mellitus → 8/40 patients
- High blood cholesterol → 37/40 patients

One patient of the *study group* had no cardiovascular risk factors.

Risk factors of the *control group*:

- Smoking → 4/10 patients
- Obesity → 3/10 patients
- Hypertension (RR ≥ 140/90 mmHg) → 7/10 patients
- Diabetes mellitus → 1/10 patients
- High blood cholesterol → 2/10 patients

Two patients of the *control group* had no cardiovascular risk factors.

In the *study group*, 40 patients had CAD diagnosed by coronary angiography.

The *control group* consisted of patients suffering from valve disease only, which was diagnosed preoperatively by transthoracic echocardiography:

- Five patients with aortic stenosis → aortic valve replacement
- One patient with combined aortic stenosis and insufficiency → aortic valve replacement
- One patient with aortic insufficiency → aortic valve replacement
- Three patients with mitral insufficiency → mitral valve reconstruction

Coronary angiography therefore was normal.

Patients with arrhythmia, allergy to iodinated contrast media, and renal insufficiency (serum creatinine > 120 mmol/l) were already during patient selections excluded from the study.

The local ethics committee approved the study protocol and written informed consent was obtained from all patients.

2.2. Invasive coronary angiography

According to the standard techniques, a conventional selective coronary angiography on a Philips Integris Allura 9 Biplanesystem was performed. The contrast medium (Ultravist, Schering) consumption including the levogram averaged 140 ml. 5F diagnostic catheters (Cordis, Johnson & Johnson) were used.

The multiple views were stored on a CD-ROM and two cardiac surgeons blinded to the results examined the images for evaluation of the coronary arteries preoperatively. In this study, a modified classification of the guidelines of the American Heart Association [5] was applied. The coronary arteries were segmented in 11 parts: Subdivision of the right coronary artery (RCA) and the left anterior descending artery (LAD) in a proximal, middle and distal part; the circumflex branch (CX) in a proximal and distal segment; the left main (LM), the diagonal branch 1 (D1) of the LAD and the first marginal branch of the CX (1st marg.) were considered as being independent segments. If the diameter reduction was >50%, the accordant vessel segment was scored as being significantly stenosed. Coronary arteries with diameter as large as 1.5 mm were analysed including those vessels distal to an occlusion.

2.3. 64-Slice CT

All CT scans were performed on a 64-slice scanner with a 0.37 s rotation time (Somatom Sensation 64, Siemens, Forchheim, Germany). No additional beta-blockers were administered prior to CT. A bolus of 80 ml iodixanol (Visipaque 320 mgI/ml, Amersham Health, Buckinghamshire, UK) was injected into an antecubital vein at a flow rate of 5 ml/s, followed by a 50 ml saline chasing bolus. Start delay was defined by bolus tracking in the ascending aorta and scan start was automatically initiated 5 s after reaching the threshold (140 Hounsfield Units, HU). After that, scanning was performed from the tracheal bifurcation to the diaphragm using the following parameters: X-ray tube potential 120 kV, effective tube current 500—680 mAs, detector collimation 32 mm × 0.6 mm, table feed 9.2 mm/rotation, and pitch 0.24. Depending on the individual anatomy, the field-of-view was fitted to the cardiac size in each patient (211 ± 19 mm; range, 182—268 mm). We used retrospective electrocardiographic (ECG) gating for optimal heart phase selection [23]. The implemented adaptive cardio volume approach was used for data reconstruction. Depending on the heart rate throughout the examination, axial slices were reconstructed synchronized to the ECG by a single sector (≤65 beats per minute [bpm]) or two-sector algorithm (>65 bpm) using data from one or two consecutive heartbeats [4,22]. When necessary, R-wave indicators were manually repositioned to improve the quality of synchronization. Images were reconstructed in 5% intervals of the cardiac cycle to allow assessment of coronary arteries at that cardiac phase with minimal vessel motion. Slices with a thickness of 1 mm (increment 0.8 mm) and a medium soft-tissue reconstruction kernel (B30f) were used for evaluating coronary arteries.

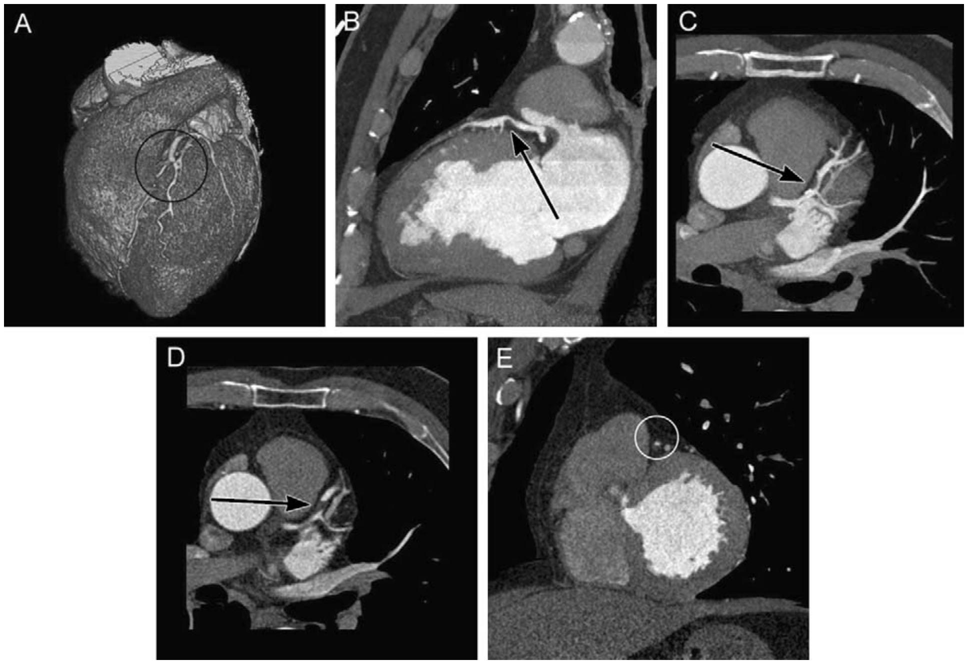

Fig. 1. VRT image of the LAD (A). MIP image in an oblique sagittal (B, arrow) and oblique transverse (C, arrow) plane. MPR parallel (D, arrow) and orthogonal (E, circle) to the vessel. In combination of these techniques, a non-calcified significant stenosis in the middle segment of the LAD is evaluable.

2.4. CT image analysis

The whole dataset was saved in the picture archiving and communicating system of the hospital (PACS) and was transferred for image analysis to a dedicated workstation (Second Wizard, Siemens) equipped with a 4D software (Syngo Argus, Siemens). The CT image presentation to the cardiovascular surgeons was performed by a radiologist. Each evaluation started with a 3D reconstruction of the heart in the volume rendering technique (VRT) (Fig. 1A). This technique provides an overview about the courses of the arteries, possible occlusions or opacified adjacent structures. Thereafter, each segment was analysed in a plane parallel and orthogonal to the course of the artery. For improved visualization of crucial locations, the techniques of multiplanar reformations (MPR) and maximum intensity projections (MIP) were used, Fig. 1B–E. Combinations of all techniques (3D heart models and 2D images in two planes) enabling different views of the interior and exterior surface of the coronary arteries optimise the image evaluation.

Analysis of the coronary artery stenoses by CT was accomplished in the same pattern as mentioned above for ICA.

Two blinded and independent readers from the clinic for cardiovascular surgery without any knowledge of the patient's medical history and of the results from ICA investigated the CT scans with regard to hemodynamically significant stenoses using the same evaluation criteria like ICA. Segments with a diameter down to 1.5 mm including those distal to occlusions were analysed. A significant stenosis was defined as vessel lumen constriction more than 50%. Also, the same classification – 11 segments of the coronary vessel system – already described for the evaluation of the ICA was used for the analysis of CT.

The type of stenosing plaque was defined as being calcified, mixed (calcified and non-calcified fractions), and non-calcified. Since intravascular ultrasound was not applied, no differentiation of plaque qualities could be performed with ICA.

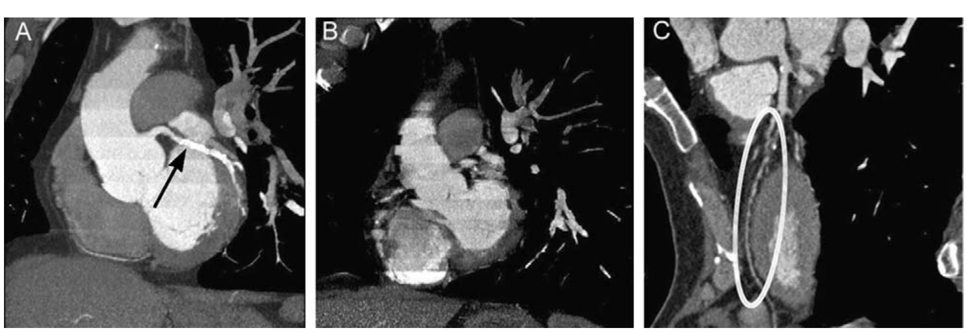

Fig. 2. Illustrations of image limitations. Strong calcifications in the middle segment of the LAD demonstrated in an oblique MIP (A, arrow). Motion artefacts prevent any image analysis (B). Small vessel diameter starting in the middle segment makes detailed evaluation difficult (C, circle).

Image quality of 64-slice CT was defined as follows:

- Reliable analysis: optimal diagnostic image quality and conditions for evaluation by both readers
- Unreliable analysis: reduced diagnostic image quality and limited conditions for evaluation by readers
- Not assessable: strongly reduced image quality with no possibility for analysis by the readers

Different reasons for image quality degradation were defined as follows:

- Strong vessel wall calcifications (Fig. 2A)
- Motion artefacts (Fig. 2B)
- Small vessel diameter (Fig. 2C)

2.5. Statistical analysis

This study investigated the diagnostic accuracy of 64-slice CT for detection of coronary artery stenoses in $\geq$1.5 mm diameter segments. The location and number of significant stenoses were documented and compared with the results from ICA, the latter of which was considered the standard of reference.

Images of the coronary arteries from CT and ICA of both groups (pathologic/non-pathologic coronary vessels) were evaluated by two blinded cardiovascular surgeons. The concordance between the both reviewers for diagnosing significant coronary artery stenosis was calculated by the Cohen's kappa-value [6] and appraised by the instructions of Landis and Koch [7].

Sensitivity, specificity, negative and positive predictive value were calculated for the group of patients with excellent image quality and for all patients together (including reduced and not assessable image quality) and between the group of CAD patients and the group of valve disease.

Quantitative variables were expressed as mean $\pm$ stan-standard deviation and categorical variables as frequencies or percentages.

3. Results

ICA and 64-slice CT were successfully performed in all 50 patients without complications. Eleven segments in each patient and consequently a total of 550 segments in all 50 patients were analysed.

The mean heart rate during the CT scan was 65 $\pm$ 11 bpm with a range of 38–89 bpm.

The overall CT scan time was approximately 12 s (range 10–13 s) and the mean total time for the examination was less than 13 min (range 8–14 min).

The inter-observer agreement between the two readers for the detection of significant coronary artery stenoses with both imaging modalities was excellent (kappa-value of 0.93 for CT and 0.95 for ICA).

ICA demonstrated CAD in 80% (40/50) of the patients with at least one significant stenosis. In the 20% (10/50) patients with valvular disease, stenosis-free coronary arteries were identified. In 23% (129/550) of these segments, hemodynamically significant stenoses were detected. Three-vessel disease was diagnosed in 42% (21/50), two-vessel disease in 32% (16/50) and one-vessel disease in 6% (3/50) of the patients.

With 64-slice CT, a complete evaluation of all segments was possible in 77% (39/50) of the patients, whereas in 23% (11/50) the image quality of at least one segment was estimated as being limited but still diagnostic or being completely not assessable.

Image quality of 92% (506/550) of the segments was rated as being excellent and thus reliable for diagnosis. In 5% (27/550) of the segments, the evaluation was rated as being limited but still diagnostic, so that the two surgeons would have taken the responsibility for a diagnosis. In 3% (17/550) of the segments, both readers were not able to do any approximation, so that they were rated not assessable. Fig. 3 gives an overview about the evaluation of all segments by the two readers with 64-slice CT.

Strong vessel wall calcification, motion artefacts, and small vessel diameter were the reasons for a limited or not assessable quality of 64-slice CT, with the most frequent cause of 50% (22/44) being massive vessel wall calcification which caused beam hardening artefacts followed by motion artefacts in 34% (15/44) (Table 1).

Thirty-nine percent (17/44) of reduced reliability affected the RCA, 41% (18/44) the LAD including D1 and 20% (9/44) the CX including 1st marginal branch. Five percent (6/150) of all RCA segments were considered not reliable due to motion artefacts and 4% (4/150) due to strong vessel wall calcifications. Two segments (middle and distal) were not assessable because of artefacts caused by a pacemaker lead in the right atrium. Three percent (6/200) of the LAD segments including D1 were not reliable because of strong vessel wall calcifications and 5% (10/200) because of motion artefacts.

In the MSCT evaluation, a three-vessel disease was present in 32% (16/50), a two-vessel disease in 42% (21/50), a one-vessel disease in 8% (4/50) and no vessel disease in 18% (9/50). With ICA, 128 significant stenosis were detected, 111 of them were also identified with 64-slice CT (sensitivity 86%). Four hundred and four of the 422 disease-free segments in the ICA were found with CT (specificity 96%). Nineteen false-positive and 14 false-negative findings of CT were found. In addition, three significant lesions were missed with CT in unassessable segments and were thus classified as false-negative. The positive predictive value was 86% and the negative predictive value was 96%.

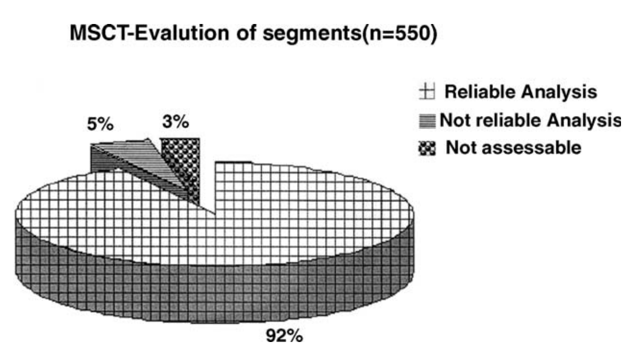

Fig. 3. Percentages of complete and incomplete analysis of 550 segments in 50 patients. Subdivision for evaluation in reliable analysis, limited analysis, and not assessable segments.

Table 1
Reasons for reduced image quality according to the distribution in different branches

	Unreliable analysis	Not assessable	RCA	LAD inc. D1	CX including 1st marg.
Strong calcifications	34% (15/44)	16% (7/44)	16% (7/44)	23% (10/44)	11% (5/44)
Motion artefacts	20% (9/44)	13% (6/44)	13% (6/44)	13% (6/44)	7% (3/44)
Small diameter	7% (3/44)	5% (2/44)	5% (2/44)	5% (2/44)	2% (1/44)
Other reasons	0	5% (2/44) [a]	5% (2/44) [a]	0	0

[a] PM-artefacts.

Table 2
Accuracy of 64-slice CT for the detection of significant coronary artery stenoses with analysis performed by cardiovascular surgeons

	Reliable quality, unreliable analysis, and not assessable quality	Reliable segments
Sensitivity (%)	87	93
Specificity (%)	96	97
Positive predictive value (%)	86	91
Negative predictive value (%)	96	98

The results for the group including all segments and the group including only those segments with excellent image quality enabling reliable analysis are shown.

In the segments that were rated reliable by the readers, the sensitivity increased to 93% and the specificity to 97%. Nineteen wrong diagnosis were made (11 false-positive, 8 false-negative). Also, the positive and negative predictive values increased to 91% and 98%, respectively. Results are summarized in Table 2.

In the 40 patients with CAD, at least one significant stenosis was correctly identified with 64-slice CT.

All analysed segments (110/110) of the patients with valvular disease were reliable. Ninety-nine percent (109/110) of the evaluated segments were correctly excluded a significant stenosis. In one segment was found a significant stenosis with CT, whereas the ICA illustrated wall irregularities but normal findings. So in 9 of the 10 patients with valvular disease, CAD could be correctly excluded by CT, whereas in one patient with an inconspicuous ICA an one-vessel disease was found with CT.

With 64-slice CT, 24% of all detected significant coronary lesions were non-calcified. Seventy-six percent of the significant stenoses were mixed and had at least one calcified part, whereas 45% of them were completely calcified. The different lesion types are demonstrated in Fig. 4.

Fig. 5 illustrates a non-calcified significant stenosis in the distal segment of the RCA. Although both the VRT image as well as ICA showed a significant stenosis, no analysis of the plaque quality was possible (Fig. 5A and B). Using curved MPR and the MIP technique, a non-calcified plaque could be clearly identified (Fig. 5C and D). In this patient, an endarterectomy of the distal RCA at the site of the stenosis was performed (Fig. 5E). The histology of the specimen showed no calcifications but abundant cholesterol granulomas.

Fig. 6 illustrates a significant calcified lesion in the RCA. The MPR illustrates the stenosis in the middle segment of the RCA in the longitudinal and orthogonal plane (Fig. 6C and D). There are also multiple, eccentric, non-stenotic, calcified plaques, which were not visualized with ICA.

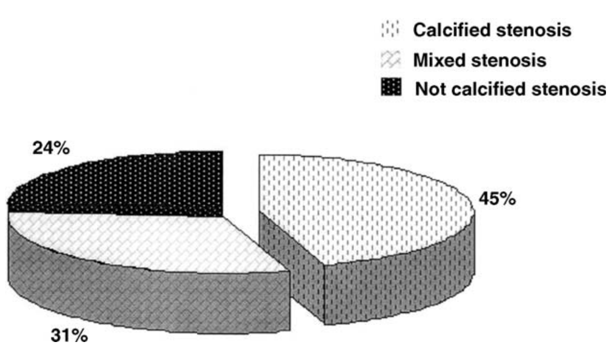

Fig. 4. Nature of stenosing plaques as assessed with 64-slice CT.

4. Discussion

The recent introduction of a new CT scanner generation with improved spatial and temporal resolution generating 64 slices per rotation promises an improvement of image quality that may allow a more precise evaluation of coronary artery stenosis. The forerunner models 4-slice and 16-slice CT showed sensitivities for detection of significant stenoses of 58—86% [8,9] and 73—95% [3,10]. This study has shown for the first time that 64-slice CT image interpretation and diagnosis of significant stenosis by cardiovascular surgeons is feasible with a high diagnostic accuracy. Although a direct comparison of the sensitivities to the above mentioned studies is not permitted due to differences in imaging protocols and patient populations, the sensitivity of 93% and specificity of 97% for those segments with best image quality in our study suggest a definite improvement. The values were lower when including all segments into the analysis reaching a sensitivity of 87% and a specificity of 96%. We analysed all arteries having a diameter >1.5mm, whereas previous studies were limited to segments with a diameter of >2 mm [3,10]. Nevertheless, the percentage of not assessable segments in our study was 3% and was thus drastically decreased. This is even more noteworthy, since we did not administered additional beta-blockers or nitrates to reduce heart rates and to expand the diameter of the coronary arteries. Moreover, our study population was a high prevalence cohort for CAD and had a large amount of coronary artery wall calcifications, which is another known factor decreasing image quality of coronary CT. In addition, this setting with patients having a high pre-test probability of the coronary artery disease may have resulted in an overestimation of the ability of MSCT to detect coronary stenoses. A patient selection bias may probably limit the transfer of these results to clinical practice.

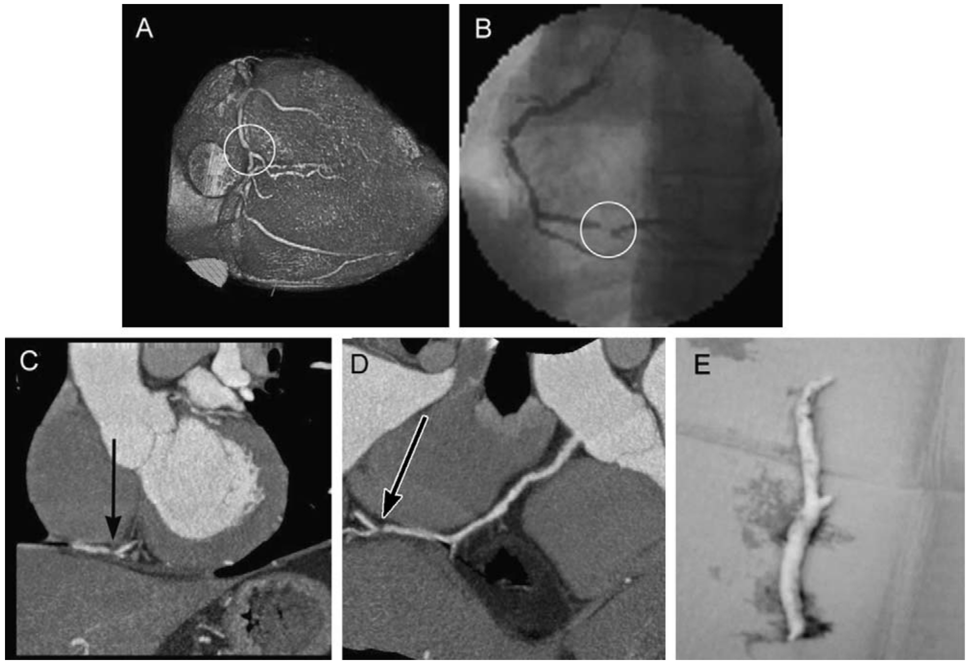

Fig. 5. Illustration of a significant stenosis in the VRT image (A, circle) and ICA (B, circle) in the distal segment of the RCA. MPR (C, arrow) and oblique MIP (D, curved) images demonstrate a non-calcified stenosis (C and D). Endarterectomy specimen of the distal RCA at the site of stenosis (E).

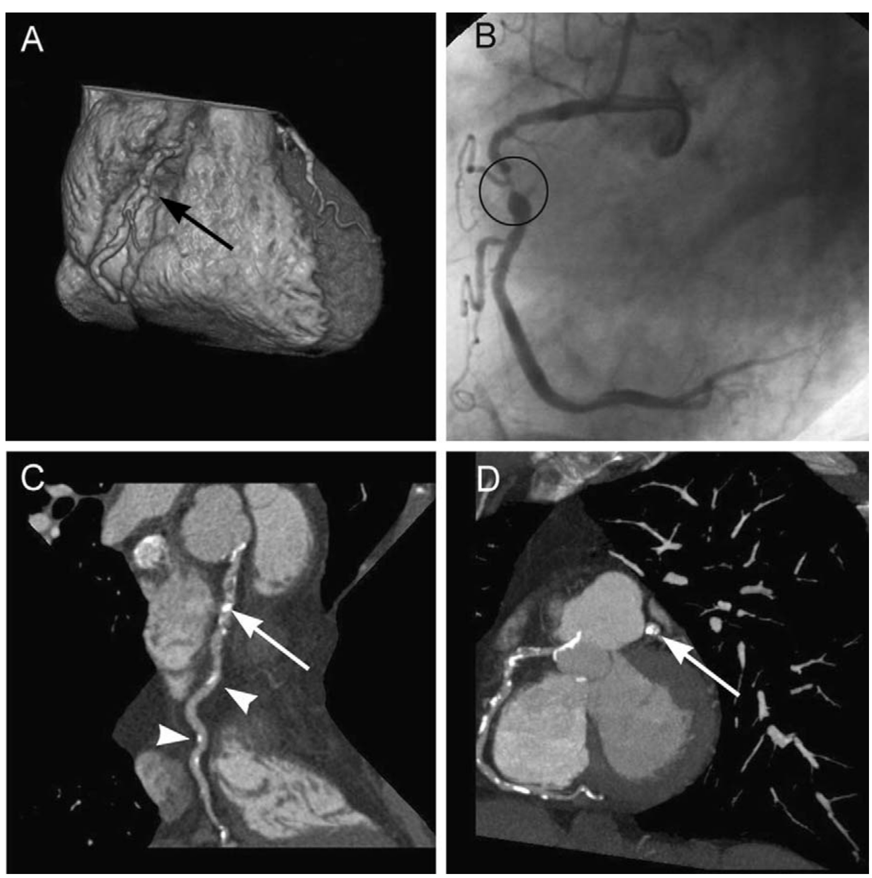

Fig. 6. Significant lesion in the middle segment of the RCA demonstrated in the VRT image (A, arrow) and ICA (B, circle). Verification of a calcified stenosis in MPR images parallel (C, arrow) and orthogonal (D, arrow) to the vessel. CT demonstrates in addition a calcified non-stenotic plaque, which was not visible with ICA (C, arrowheads).

To comply for the variable heart rates in our study (ranging from 38 to 89 bpm), several reconstruction intervals relative to the cardiac cycle were performed enabling an individual choice of the phase with minimal vessel motion for each segment. This leads to a reduction of motion artefacts for most of the arteries and therefore allows the reliable assessment of segments with higher heart rates. A still unsolved problem of coronary artery CT is the dependency on a sinus rhythm, which makes coronary artery evaluation in patients with arrhythmia almost impossible. In the most segments where image quality was reduced, evaluation was still possible and was considered diagnostic. Only 3% were rated as being completely not evaluable. In contrast to 4-slice CT, up to 32% of the coronary segments had to be excluded from the analysis due to reduced image quality [11]. Compared with 4-slice CT and 16-slice CT investigations, this constitutes a major improvement and is not only explained by improved acquisition time but also by the fact that the entire scan time is significantly shortened, making this technology more robust against respiratory and motion artefacts of the patient.

In recent studies, strong calcifications were a limiting factor for the analysis of coronary arteries [1,3]. Despite improvements in temporal resolution, spatial resolution, and speed of volume coverage of 64-slice CT compared to previous CT scanner types, lesions with extensive calcified components and implanted coronary stents still compromise the accuracy of MDCT coronary angiography. These high-density structures cause beam hardening and partial volume artefacts resulting in the so-called 'blooming'. Despite of careful image reconstruction with sharp convolution kernels and bone window settings, the assessment of complex and unstable coronary lesions is usually compromised in heavily calcified vessels and especially at the site of implanted stents [12,13]. On the other hand, stent lumen visibility largely depends on the stent size and type [14]. More purpose-planned studies are necessary to investigate the possibilities of reducing the limits for evaluation of patients with previous stent implantation and/or severe lesions.

In this study, calcifications caused beam-hardening artefacts and thus impaired lumen visualization in 4% of all analysed segments in 50% of the limited and non-assessable segments. On the other hand, all false-positive significant stenoses with CT were depicted with ICA as wall irregularities. Although ICA enables the illustration of the lumen contour, it provides less information about wall or plaque composition. For characterisation and quantification of plaque or lumen sizes, intravascular ultrasound (IVUS) is considered the method of choice.

We were able to characterize the quality of the stenosing plaque without comparison to IVUS as gold standard to verify these results. However, the ability of 16-slice CT for plaque quality diagnosis was already demonstrated in different previous studies [15—17]. In our study population, 24% of the plaques were non-calcified. More than three-quarter of all significant stenoses had a calcified part and 45% of them were purely calcified. In addition, non-significant calcified plaques were not visible or only seen as wall irregularities with ICA which could be a potential advantage for using 64-slice CT as preoperative planning tool in patients undergoing coronary anastomoses in minimally invasive procedures (Fig. 4).

Another important point of discussion includes the advancements and possibilities of CT image post-processing and image evaluation. At present, the radiologist is not only responsible for the protocol and quality and of the CT examination but also for the image post-processing and evaluation. The radiologist usually conducts a preselection of images that potentially could lead to an evaluation bias of the second reader, i.e., in this study the cardiovascular surgeon. This preselection of images could well be the reason for the excellent inter-observer agreement of both readers (kappa-value of 0.93), because all images were presented to them by the same radiologist. In addition, the experience and technical abilities of the responsible radiologist are very important. This is a major difference to ICA where the study can be analysed by different people independent of the cardiologists because standardized projection are used. Certainly, a standardized protocol for data post-processing and image evaluation of coronary arteries with 64-slice CT is mandatory and should be the objective of prospective studies in future.

When interpreting the existing literature [18,12,19] and including our experience, the future role of 64-slice CT in clinical practise could be as follows:

1. The image modality could be a diagnostic tool in patients with atypical or unclear thoracic symptoms having some cardiovascular risk factors.
2. 64-Slice CT could be able to serve as a tool to exclude significant CAD. For example, ICA is performed at present for patients older than 50 years with a valve disease to exclude CAD, even when there is no clinical suspicion of diseased coronary vessels. In these cases, it would be much more convenient for the patients to undergo a CT scan without being exposed to the inherent risks of ICA.
3. Preoperative planning: Exact localisation of coronary arteries in relation to surrounding structures and identification of significant stenosis or vessel wall calcifications, as well as an intramyocardial course of the arteries could dramatically help to plan and conduct the surgical procedure.

   Particularly in minimally invasive procedures where the access is limited, shorter pump runs on the heart-lung machine and an improved hemodynamic handling in patients operated on off-pump could result. Similar to the coronary arteries, evaluation of internal mammary arteries and ascending aorta for planning the operation in terms of graft harvesting and cannulation site can be performed in the same CT examination.

   Similarly, morphologic abnormalities of the aortic and mitral valve is feasible within the same CT examination to identify and quantify calcifications or morphologic abnormalities [20,21].

It is not yet clear what clinical role coronary artery CT will play in future when evaluating patients with suspected CAD. Nevertheless, 64-slice CT provides considerable improvements with regard to a better spatial and temporal resolution and to an increased and faster volume coverage. Still existing limitations are the exclusion of patients with arrhythmia and limiting factors such as strong vessel wall calcifications and motion artefacts which all can cause a restricted image interpretation. Certainly, 64-slice CT can serve as a complementary imaging technique to ICA but cannot replace it in clinical routine at this moment. Its potential as a screening test must be compared with existing alternatives, such as conventional treadmill and nuclear stress testing. In the near future, however, coronary CT might be used to screen individuals with multiple risk factors and to identify critical lesions.

Acknowledgement

This research has been supported by the National Center of Competence in Research, Computer Aided and Image Guided Medical Interventions (NCCR CO-ME) of the Swiss National Science Foundation.

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Appendix A. Conference discussion

Dr P. Kolh (*Liege, Belgium*): Just a quick question concerning your conclusion. What would it take for CT to replace angio?

Dr Plass: We should not have the goal completely to replace the coronary angiography at the moment. We should see a differentiated view for the future use. For diagnostic examination of an old patient with risk factors for cardiac disease, in the moment the application of the multislice CT is not indicated. A patient without any risk factors and it should be done an exclusion diagnostic for a coronary artery disease then in our view the 64-MSCT is the better choice. Also for evaluation of younger or older patients without any risk factors and a mitral insufficiency or an aortic insufficiency, then we think also the use of MSCT instead of coronary angiography is the better choice. For preoperative planning the MSCT could be very useful in the future, especially if you take a look to the minimally invasive techniques, and for example, cohesive with the calcified plaques I illustrated before, which are differentiable in the coronary angiography. If you plan a distal anastomosis or some anatomical speciality, then for preop planning the 64-MSCT should show the value.

And the last point, for postoperative follow-up, for sure, especially for patients with high morbidity and mortality, if you want to have long-term follow-up, the 64-MSCT is often a better choice than the coronary angiography.

Mr A. Ritchie (*Cambridge, United Kingdom*): For those of us who might envisage that this may one day replace diagnostic angiography despite what you say, we need to know a simple piece of information, and that is, how long does it take to do one of these scans in each patient?

Dr Plass: You mean the MSCT scan?

Mr Ritchie: Yes. How long does it take to get one patient through and get the information?

Dr Plass: The examination itself does not need a long time. It needs around 15—20 s; altogether with lying down the patient and organisation, it is around 10 min. The image reconstruction is a little bit more time consuming, but it is also improved with the 64-MSCT, we need afterwards around 30 min to get an image reconstruction for an overview and possible evaluation of his vessels.